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Curriculum materials and methods for studying science at varying rates of progress were demonstrated to selected upper elementary teachers, supervisors, and principals throughout Virginia. Analyzed were the relationships between student performance and related classroom and learner variables. Teachers used programed materials in inservice training as a means of acquiring knowledge and skill in science as well as an understanding of the techniques of programming. Major outcomes of the study were (1) students and teachers were enthusiastic and/or favorable towards this approach, and procedures were effectively implemented, (2) students followed the programed procedures with minimum direction, (3) a courteous, patient and sympathetic atmosphere typically prevailed in the classrooms, (4) teachers became increasingly independent, (5) supervisory and administrative involvement was cooperative and effective, and (6) the analysis of student performance indicated the influence of the classroom climate and the student variables of intelligence, initial science achievement, maturity, sex, and grade level. (GR)

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FINAL REPORT
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THE TEACHING OF UPPER ELEMENTARY SCHOOL SCIENCE USING PROGRAMED MATERIALS COUPLED WITH STUDENT PERFORMED EXPERIMENTS

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THE TEACHING OF UPPER ELEMENTARY SCHOOL SCIENCE USING PROGRAMED MATERIALS COUPLED WITH STUDENT PERFORMED EXPERIMENTS

Mary Ann MacDougall
University of Virginia
Charlottesville, Virginia

August, 1968

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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Reported here are the results of two years of the demonstration of a programed science approach, coupled with the individual student performance of laboratory experiments. The study involved an evaluation of the materials development, training, supervisory, and demonstration procedures necessary to a successful implementation of instructional techniques, student attainment of objectives, and demonstration of this approach.

We are grateful to all the teachers, students, supervisors, and principals who participated in this program. It is important to note that the superintendents of Albemarle, Bland, Chesapeake, Henrico, Nelson, Martinsville School and Waynesboro Divisions made it possible for the research to be conducted by giving their approval. Their support is sincerely appreciated.

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SUMMARY

Background of the Study.

In 1962 the Bureau of Educational Research initiated a series of studies to test the efficacy of programed science materials at the fourth-grade level, coupled with an investigation of the influence of the individual performance by children of simple science experiments as they completed framed sections of the programed materials. A one-year course of study in programed science and related laboratory experiences was developed, field tested, revised and evaluated under several conditions. The findings over a four-year period suggested that the materials were effective in attainment of science achievement, sustained motivation, and a favorable reaction from teachers and pupils.

Valuable side effects of this approach to teaching science included: (1) the in-service training benefits for teachers in elementary science, (2) the confidence obviously developed by teachers for doing experiments rather than avoiding them, (3) the aid for those teachers who had not learned how to free individuals for small group and individualized work in the classroom, (4) the evident shouldering of more responsibility by children for their own learning, (5) the strengthening of a science program where teachers are less than prepared in science, (6) the opportunity for dealing more effectively unusually far above the class in achievement in science, (7) the lack of necessity for duplicate sets of science equipment.

In contrast to the background studies in which the role of the teacher was prescribed to monitor the programed materials, the demonstration project encouraged individual adaptation of the programed approach to an organized instructional pattern. Major concerns were (1) classroom organization and the teacher's participation in the programed instructional process, and (2) the integration of classroom procedures and activities complementary to the experiences of the children who progress at an exceptionally fast rate or who are retarded by low reading ability. In short, the role of the teacher within the instructional process was the primary concern of the study.

Objectives.

The major objectives of the study are outlined below:

1. To provide for a period of nine months teaching-demonstration centers throughout Virginia to which teachers, supervisors and elementary school principals may come for observation.

2. To train and develop the leadership potential in selected fourth, fifth, and sixth grade teachers in the use and rationale of the programed science materials in the following ways:

a. to develop the laboratory skills of the teachers while at the same time instilling in them confidence in their own ability to perform numerous simple science experiments.

b. to introduce the teachers, their principals, and supervisors to the new methods, materials and underlying concepts.

c. to encourage the critical evaluation of this approach and the participation in continuing activities in elementary science.

3. To investigate the factor of maturation as it relates to student achievement in science, ability, sex, and attitudes toward the study of science.

Procedures.

The following procedures were observed:

1. Materials development. The evaluation of programed materials was accomplished in background studies. The Teacher Handbook was prepared for summer training and fall orientation.

2. Teacher Training. The summer program involved the study of the programed materials, coupled with laboratory experiences, a presentation of the rationale of programing and discussion of instructional techniques.

The orientation sessions introduced superintendents, principals, supervisors and teachers to background studies, the purposes of the demonstration project, and the nature of the programed approach. In-service training was accomplished through supervisory procedures.

3. Supervisory procedures. Two faculty members and 6 graduate students were responsible for the supervision of the 24 classes. Training sessions were held for those students not familiar with the classroom application. The supervisory responsibilities of these students were initially carried out as a team with an experienced person. Each supervisor assumed the primary responsibility to coordinate and administer the program in a given set of classes. Throughout the year, supervisors were generally rotated to several classroom situations to counterbalance bias in supervision and to present a broader range of experience.

4. Demonstration procedures. The involvement of supervisory and administrative school personnel was initiated by each school division. Dissemination throughout the State was encouraged by the Summer Evaluation Conference, and assistance to follow-up studies during 1967-68. Continuing efforts focus on training and coordination with the Virginia State Department of Education.

Findings.

It appeared from teacher and supervisory observations that the implementation of the programed materials was effective for the following reasons: (1) students and teachers were enthusiastic and/or favorable towards this approach, (2) students followed the programed procedures with minimum of direction, (3) over 50% - most students concentrated on reading the programed text and performed experiments with little confusion, (4) a courteous, patient and sympathetic atmosphere typically prevailed in the classrooms (5) teachers became increasingly independent, (6) those organizational features (students' learning rate, unit test procedures, instructional planning and control) and student understanding of the purpose of the experiment which were given a relatively lower rating than the other items reflected, nonetheless, a positive tendency, and (7) supervisory and administrative involvement was cooperative and effective.

The student attainment of behavioral objectives was analyzed by relating three levels of classroom climate, three grade levels, (4, 5, 6), age, sex, intelligence, and initial science achievement to measures of final science achievement. Intelligence and initial science achievement generally influenced the student's final test performance. The level of classroom climate (observation of pupil behaviors and instructional procedures) influenced the final achievement of lower ability students. The maturity of students did not influence final achievement relative to the student's intelligence and initial science achievement. The programed tests appeared appropriate for average and upper ability fourth and fifth graders and lower ability sixth-grade students.

The specific objectives of the instructional system readily identified areas of supervisory or instructional assistance. The laboratory experiments, in particular, offered a specific means by which the supervisor or school principal became involved in the elementary science program and the teacher related more closely to the science facilities available in the school. Requests to continue with the project and the favorable response to the program suggested this approach as an effective demonstration of programed science with laboratory experiments at the upper elementary school level.

CHAPTER I

STATEMENT OF PURPOSE AND BACKGROUND

I. INTRODUCTION

The many rapid changes taking place in the complex society of the United States continue to escalate to a degree previously unknown in the history of mankind. The impact of the scientific and technological demands can be observed through the awareness of and concern for the responsibility of our educational system to prepare all segments of the population to live in and adjust to this dynamic society. One outgrowth of a rapidly expanding technology is the emphasis on the study of science *per se*; a second, the organization of a curriculum which will better meet the educational objectives of each child.

The intensive efforts of national agencies to encourage and sponsor the extensive retraining of secondary school science teachers and the development of many new science curriculums combined to bring about greater pressures on the elementary school to upgrade the teaching of science. This renewed interest in science education in the 1950's focused on the extremes in quality and quantity of the science being taught and the concern of many teachers who had not anticipated the recent scientific emphasis in their training. A survey of the status of science in the elementary schools of Virginia (35), conducted by the Bureau of Educational Research in 1962, supported these observations in an evaluation of the role of the teacher in the elementary school science program.

The development of the theory of programed instruction and its expanded use in a greater variety of human learning situations in the 1950's suggested the possibility of this approach in the re-evaluation of the science curriculum and an improved science instruction, providing more substantially for individual differences in rate of learning and achievement of students. In 1962 the Bureau of Educational Research initiated a series of studies to test the efficacy of programed science materials at the fourth-grade level, coupled with an investigation of the influence of the individual performance by children of simple science experiments as they completed framed sections of the programed materials. A one-year course of study in programed science and related laboratory experiences was developed, field tested, revised and evaluated under several conditions. The findings over a four-year period suggested that the materials were effective in attainment of science achievement, sustained motivation, and a favorable reaction from teachers and pupils.

The subject of investigation of this report represents an extension from the stage of materials development to the implementation of the programed science approach in public elementary schools in Virginia; and, as such, the research purpose was primarily conceived of as serving an innovative function. The demonstration project, "The Teaching of Upper Elementary School Science Using Programed Materials Coupled With Student Performed Experiments," was sponsored by the Cooperative Research Branch, Health, Education and Welfare, and initiated in the summer of 1966 to accomplish this objective.

The major purpose of the study was to demonstrate via selected upper elementary teachers, supervisors and principals throughout Virginia the curricular materials and new methods developed for enabling students to study science at varying rates of progress and to perform individually numerous science experiments. The programed materials were first used in the in-service training of teachers as a means of acquiring knowledge and skill in science and an understanding of the techniques and rationale of the programed approach. Adapting this approach to the teaching of upper elementary school science provided experiences in the application of training objectives and a demonstration center for teaching and administrative personnel of the school and nearby districts. A secondary purpose of the study was to analyze the relationships between student success and related characteristics, particularily observing the influence of varying age and ability levels.

A summary of related background research carried out by the Bureau of Educational Research is presented below.

II. BACKGROUND RESEARCH

Despite claims for the effective teaching and learning made possible through the use of teaching machines and programed textbooks, two major questions arose in designing an evaluation of the programed science materials: (1) the feasibility of programed learning *per se* within the context of modern elementary curriculum theory; (2) if the former, then the nature and form of this approach to teaching areas within the curriculum. Thus, there is not only the question of whether programed learning is feasible in meeting some of the objectives of the elementary school curriculum, but which approaches might be most effective. Studies such as that by Keislar and McNeil (43), in which first-grade children were taught by scientific explanations by means of a 432 frame program, and by Carpenter (9), who investigated the performance of fourth-graders taught science by traditional methods or by demonstrations and experimentation encouraged study of the feasibility of this approach for elementary science.

Stages of Development

Phase I. The first phase of this project was a short pilot study designed to ascertain whether programed instruction with student performed experiments at the fourth-grade level appeared to have promise as a means of teaching elementary school science. Dutton's study (18) revealed: (1) the experimental group was significantly higher in achievement than the control group taught by more conventional means, (2) students did proceed at individual rates of speed and were capable of individually performing experiments, (3) students and teachers liked the materials and the program; (4) the individual student laboratories appeared to be a motivational factor.

Phase II. Having demonstrated the promise of programed science materials with individually performed student experiments, the Bureau staff then undertook an extensive, year-long project. The primary purpose of this project was to develop, through field testing and analysis, a complete course of study in science for the fourth grade. Skinner's small step approach and his theory of cueing with a linear structure were used, employing constructed responses with immediate knowledge of results. The results of this study (34) revealed that on STEP science tests, used as a post test, no significant differences existed between the experimental group, taught by programed methods, and the control group, taught by conventional techniques. In addition, the final mean achievement of both groups was comparable to the national norm. Also noted was the fact that both teachers and students exhibited considerable interest in the program.

Phases III and IV were supported by the Office of Education, Cooperative Research Project No. 1972, "A Comparison of Three Methods of Teaching Elementary School Science Involving Programmed Learning (33)." This study involved the first major attempt to evaluate the programed materials in a controlled situation.

Phase III. The general purpose of Phase III was to compare the instructional effectiveness of teaching science at the fourth-grade level using the three methods:

(1) Use of a sequence of programed science materials coupled with performance, individually or in pairs, of simple experimental exercises by the children.

(2) Use of the same programed materials by other students, who only read about the experiments instead of doing them.

(3) Use of the same programed materials rewritten in textbook format, with assignments fixed by the teachers and with periodic teacher demonstrations of the experiments.

Instructional effectiveness was defined as science achievement, interest and attitudes, laboratory resourcefulness, and retention of science material.

The results of the study showed no significant differences in achievement, retention and interest among the three groups. The attitude of the second group, which had no direct contact with experimentation, was significantly lower than the other two groups at the end of the experimental period. A laboratory resourcefulness test indicated significantly higher performance for the programed group with laboratory activities.

Phase IV. Programed texts were modified to investigate the influence of the variables: (a) constructed response vs. multiple choice, (b) all answers vs. partial feedback, and (c) branching vs. linear programing. The versions were compared on the measures of instructional effectiveness defined in Phase III of the evaluation. The findings did not indicate the general superiority of any one version.

A one-year extension of the project introduced elements of critical thinking into three units of the programed materials. The results showed that students studying from the modified programed materials had significantly greater mean performance in critical thinking ability than did the control group. Constantinides (11) studied the relationships of personality, social adjustment, intelligence, and science achievement with critical thinking.

Related studies focused on curriculum (33), prediction (56), and readability (68) analyses. Taylor (69) observed teacher attitudes, pupil behavior and content attributes in his analysis of the science achievement of students.

Implications for the Demonstration Project

The investigators concluded, after three years of work with programed science materials in over twenty-five fourth-grade classes, that this approach can be a valuable adjunct to a modern elementary school science program for the following reasons:

1. Feasibility - Students can and do proceed at individual rates; they perform most laboratory experiments by themselves and are not generally distracted by the activity of other students at the experiment table.

2. Instructional Effectiveness - The investigators were not able to demonstrate that this approach is superior to conventional teaching. However, since the logic of the programed structure was contained in the control texts, control teachers were provided laboratory materials and supervisory assistance, the investigators concluded that the use of the materials might well offer a more efficacious program in systems where elementary science was not emphasized. Weaknesses in programing techniques likely accounted for, in part, the insignificant differences among programed versions and teaching methods.

   The investigators concluded that the laboratory experiences contributed in large measure to the sustained motivation of students over one year, as well as contributing to their ability to solve new problems.

3. Student and Teacher Reactions - About 80% of the teachers favored the approach, although all felt there was room for improvement in specific respects. Positive teacher observations included the development in pupils of good work habits, preparation and interest in science, and the instructional benefit for the teacher. Teachers found the less mature pupils and poor readers to need additional assistance.

   The vast majority of students remained positively oriented toward the approach throughout the course of study. The performance of experiments, learning about new things and the independence in pacing and teaching were the most frequently occurring reactions expressed by the students.

Valuable side effects of this approach to teaching science included: (1) the in-service training benefits for teachers in elementary science, (2) the confidence obviously developed by teachers for doing experiments rather than avoiding them, (3) the aid for those teachers who had not learned how to free individuals for small group and individualized work in the classroom, (4) the evident shouldering of more responsibility by children for their own learning, (5) the strengthening of a science program where teachers are less than prepared in science, (6) the opportunity for dealing more effectively unusually far above the class in achievement in science, (7) the lack of necessity for duplicate sets of science equipment.

In summary, the materials appeared to have a real potential in resolving some of the major problems in elementary science in Virginia. The use of the programed materials in an in-service training program appeared particularly suitable for those elementary school teachers with a limited knowledge of science, lack of confidence in their ability to teach science, and with the need and desire for experience and skills with simple laboratory equipment. Application of this approach to the classroom situation encourages instructional procedures which allow children to proceed at varying rates, deal with diverse materials, and develop independence in learning. In addition, the classroom as a teaching-demonstration center initiates a greater number of teachers and administrative personnel to the instructional process and implications of such an approach, and realizes the need to provide a greater number of elementary children with concrete experiences in science and to develop in them a positive attitude towards the study and field of science.

III. MAJOR OBJECTIVES OF THE STUDY

In contrast to the background studies in which the role of the teacher was prescribed to monitor the programed materials, the demonstration project encouraged individual adaptation of the programed approach to an organized instructional pattern. Major concerns were (1) classroom organization and the teacher's participation in the programed instructional process, and (2) the integration of classroom procedures and activities complementary to the experiences of the children who progress at an exceptionally fast rate or who are retarded by low reading ability. In short, the role of the teacher within the instructional process was the primary concern of the study.

A secondary objective observed the relationships among selected learner characteristics. Previous studies had been confined to the fourth-grade level; however, since effective placement of materials was considered relevant to further attempts at implementation, the factor of student maturity was introduced by placing the materials in fourth, fifth, and sixth grade classes. It was anticipated that the materials might be appropriate for slow readers at the sixth-grade level, a broad range of fifth-grade students and fourth-grade students of above-average reading ability.

The major objectives of the study are outlined below:

1. To provide for a period of nine months teaching-demonstration centers throughout Virginia to which teachers, supervisors and elementary school principals may come for observation.

2. To train and develop the leadership potential in selected fourth, fifth, and sixth grade teachers in the use and rationale of the programed science materials in the following ways:

   a. to develop the laboratory skills of the teachers while at the same time instilling in them confidence in their own ability to perform numerous simple science experiments.

   b. to introduce the teachers, their principals, and supervisors to the new methods, materials and underlying concepts.

   c. to encourage the critical evaluation of this approach and the participation in continuing activities in elementary science.

3. To investigate the factor of maturation as it relates to student achievement in science, ability, sex, and attitudes toward the study of science.

CHAPTER II

REVIEW OF RELATED STUDIES

The literature pertinent to research in elementary science and programed instruction is reviewed in Chapter II. The chapter concludes with a summary of related studies initiated by the Bureau of Educational Research and conducted in concert with the operation and evaluation of the demonstration project.

I. RESEARCH IN ELEMENTARY SCIENCE

Elementary science has long been a part of the American educational scene. However, the objectives, organization, and instructional methods of elementary science have been the subject of much disagreement. From such studies as Craig's early study of objectives (15), Gilbert's analysis of 30 courses of study (27), and Dubin's examination of 163 courses of study (17), the conclusion must be that there was only limited agreement concerning what to include in the elementary science curriculum, on what grade level it should be placed, and how it should be taught. This lack of agreement is emphasized by the American Educational Research Association. In the Review of Educational Research for June 1961 (1), the American Educational Research Association cites the neglect of elementary science and urges more attention to how-to-teach type studies, "rather than summaries of current practices and weaknesses." The AERA also urges attention to objectives of elementary science instruction, and the evaluation of the outcomes of those objectives.

In 1961, major steps were undertaken to develop effective, unified elementary science curricula, based on sound objectives and using currently accepted psychological principles as a basis of instruction. The opening phase of this effort consisted in part of a study by Mallinson (50), who found much confusion in the sequencing of science topics, much variation in time allotments to elementary science from school to school. This study was part of a AAAS effort to review the status of elementary science education and to formulate comprehensive plans for improvement.

A second part of this effort was a AAAS sponsored series of three regional conferences, with the objective of examining the place of science instruction in the elementary school. The conclusion reached was that science instruction should be a regular part of the curriculum of elementary schools, and that major efforts should be launched to improve both teaching and instructional materials at the elementary school level (42).

Following this report, a number of study groups was formed to grapple with the problems of elementary science instruction. The best known of these are the Elementary Science Study (ESS), of Educational Services, Inc.; the MINNEMAST program of the Minnesota Mathematics and Science Teaching Group; the Science Curriculum Improvement Study (SCIS) of the University of California at Berkeley; and "Science - A Process Approach," of the AAAS. These projects are all K-6 undertakings, and are in various stages of development. They all emphasize observation and experimentation, an approach long advocated but only now being implemented (42).

In addition to these comprehensive and heavily funded projects, elementary science instruction has also been receiving limited attention from other areas during the post-1961 period. The AERA reports that in the period June 1961 - June 1964, more fundamental questions were being considered (1). During this period, attempts were made to assess children's science concepts and interests; to develop curricular materials; and to assess organizational patterns. All in all, the period was one of exploration and rapid broad scale change.

Studies in elementary science in general seem to have little theoretical basis, and there appear to be few, if any, continuing research efforts in elementary science education. Such studies as have been published are isolated, forming no pattern. As a result, the systematic body of knowledge about elementary science education is limited in scope and sequence.

II. PROGRAMED INSTRUCTION

Beginning with Pressey's classic investigations of the 1920's and receiving added impetus from Skinner's work in the 1940's and 1950's, research on programed instruction has mushroomed. The theory of programing and the more recent adaptations to computer-assisted instruction is one of the few educational innovations which has generated excitement from both researchers and educators. The researchers' enthusiasm can be illustrated by Suppe's (67) emphasis to use a computer-based system to build a satisfactory bridge between research in learning theory and curriculum work, or the potential of programed materials suggested by Lumsdaine (48) to build a science of instruction. The development of programed instruction is distinguished from the historic concept of instructional technology, the use of media to present instructional materials, by the application of psychological learning theory to instructional practice. The second sense of instructional technology described by Lumsdaine (48) refers to the application of an underlying science, primarily learning theory, to a technology of instruction.

Differences in accepted programing techniques are now quite common. Crowder's intrinsic programing was one of the first methods at variance with Skinner's theory. Fry (22) is one of several authors who describe and contrast the programing techniques of Holland and Skinner, the Ruleg method, Crowder's rationale, and the program modification of, for example, Keislar and Pressey. Thelen's field-centered approach (70) describes a more flexible use of programed materials which allow teacher, learner, media, and subject matter interactions. Saettler (59) indicates a shift in the direction of programed instruction and teaching systems to incorporate specifications similar to those outlined by Thelen, where the individual is observed interacting with his environment in a systems approach to instruction. A systems analysis applies, when possible, theories of cybernetics, communications, logistics and/or economics, as well as learning theory, to instructional practice. The purpose of an instructional system is to build an integrated, organized system of interrelated components to produce stated goals, perhaps computer controlled, and capable of providing individualized instruction, from which can be modeled a technology of instruction (59).

The volume of effort concentrated in the area of programed instruction is evidenced in the many reviews of research and listings of available programs, some of which include Glaser's (30) and Lumsdaine and Glaser's (47) source book, Schramm's (60) summary of research, and listings of programs and research (4), (36), (54). One of the chief areas of interest to researchers has been the comparison of learning attained by students taught by programed instruction with the learning of students taught by conventional methods. Research reported in this area seems fairly evenly divided between "No significant difference" and differences which favor the programed method.

Studies which investigate the optimal conditions for concept acquisition and retention, using the programed approach, focus on (1) programing variables (typically frame and response characteristics), or (2) content presentation and organization.

Frame Characteristics

Step size. Shay (61) found that small step size takes longer, but achievement is higher if the difference in size is substantial. Coulson and Silberman (12) arrived at similar results. Exceptions to these findings may occur with brighter children, or if the response is meaningful the step size can be increased without an increase in error.

Error rate. Homme and Glaser (38) report a common finding that a large error rate within the program tends to produce a high error rate on final achievement. However, Jones (41) found better teaching items had a higher error rate. Goldback (31) suggests that size of step and low error rate does not mean that more learning occurs. His research indicates that step size can be increased with an increase in error rate, and the criterion behavior not influenced.

Prompting. Disagreement exists between confirmation and prompting. Holland (37) found confirmation superior, while Cook and Spitzer, (10) in a comparison of prompting with no overt response with confirmation and overt response, found that the prompting-no-overt-response group performed better on a paired-associate learning task. Angell and Lumsdaine (2) found prompting valid within certain limits; i.e., incomplete prompting proved superior to prompting before every response in a paired-associate learning task. Overprompting may allow students to complete blanks correctly, but post-test scores have been found significantly lower for the overprompted group (52).

Item position. The benefits of a logical ordering or systematic presentation of subject matter has common theoretical acceptance. Evans (19) compared arrangement of points given in a programed order to less structured approach, and found superior achievement using ordered material. Roe (57) found the same superiority using the Ruleg system. Gavurin and Donahue (26) carried out a similar study using materials in psychology with adults. A rentention test given one month later revealed no significant differences between the groups. Levine and Baker (46), using a geometry unit with second graders found no significant differences between the ordered and random squence groups when acquisition, retention, and transfer were measured. Payne, Krathwohl, and Gordon (52) found no observable differences between structured and random programed versions when the "judged logical interrelatedness of the material" was varied.

Response Characteristics

Overt vs. Covert. Holland's endorsement of overt responses is challenged by the findings of Roe (57), Silverman and Alter (64), Feldhusen and Birt (20), and Pressey (53). Williams (71) found a difference in performance which was related to response made when college students were used as a sample; however, Williams and Levy (72) found active participation not to be a significant factor among elementary school children. Krumboltz and Weisman (45) and Goldbeck and Campbell (32) found differences between response modes on a delayed test. Classical studies of active participation might reject these findings; however, it can be argued that the student's thinking is an active response.

Multiple Choice vs. Constructed Response. Coulson and Silberman (13) report that a constructed response group had a slightly superior performance, but more time was necessary to complete the program. Evans (19), Roe (57), Hough (39), Burton and Goldbeck (7), and Zuckerman, Marshall and Groesberg (73) found no significant differences in post-test means, using the two response modes. Fry (21) found significant differences in favor of constructed response, but when he used a multiple choice test, this mean difference disappeared.

Response meaningful. Holland (37) among others reports that a response should indicate an understanding of the item. Krumboltz (44) casts doubt on requiring a response, but if a response is required, it should not be trivial. Both responding and control groups of college students performed higher than the trivial group.

Reward. Knowledge of results or feedback receives strong support from much research. Bryan and Shuster (6) found that explanation of right or wrong response, such as used in the Crowder technique, to be a program improvement.

From a summary of the investigations, one can observe the interrelationships among the variables, which are suggestive of methods of programing, such as the Crowder or Skinner-type presentations. For example, small step, logical presentation is successful with knowledge of results or confirmation, while a less ordered or larger step approach may be compensated for by an explanation of a correct or incorrect response. Likewise, step size can be increased without loss in criterion achievement if responses are meaningful. There is evidence that overt responses may interfere with complete prompting, while prompting or cueing within limits appears successful, and overt responses seem more successful with confirmation.

The evaluative studies of the programing method and studies of the influence of programing variables are typically inconclusive. Irrespective of the short duration of many of the programs and differences in population, it seems likely that findings hold limited meaning when the programing variables are observed in isolation, or there is no common basis for defining the program structures.

Content Presentation and Organization

Gagné (18) has emphasized sequencing of programed materials as an essential factor in concept acquisition and retention. The importance of the learner achieving success on each task component has been demonstrated by Gagné (19), (20), and his associates, who have analyzed learning from a "task analysis" approach. Silberman et al (66) have also evidenced success by dividing a problem into hierarchial "learning sets," and starting students at the appropriate achievement level.

Ausubel (3) supports the use of advance organizers, or sorting and classifying models. He urges the use of expository and comparative organizers in the organization of programed material. A study by Merrill and Stolurow (51) compares six preview and review treatments and supports both Ausubel's concept of advanced organizers and Gagné's heirarchial presentation.

Branching. Branching is a common method to accommodate individual differences. Studies by Campbell (8), Coulson et al (14), and Roe (58) all indicate the improvement of branching techniques over a linear structure. Gilman and Gargula (28), using review branching in the Computer Assisted Instruction Laboratory, The Pennsylvania State University, conclude there must be a thorough investigation of those situations where branching facilitates learning and the criteria for branching decisions must be determined. The authors found no advantages for a branching strategy and cite studies by Holland, Campbell, and Glaser which are consistent with their results.

In summary, the research studies summarized above have two major implications for the implementation and demonstration of programed science materials at the elementary school level.

1. The findings which describe the influence of programing variables and the conditions which specify the selection and adaptation of programing techniques to the context of the materials are inconclusive; and, as such, the research has not resulted in a set of principles of programed instruction to guide in the writing and revision of programed materials. Thus, the additional time and cost consumed in materials development and the difficulties encountered in attempts to significantly improve the adaptation of the program must be considered in the design to implement the instructional approach. Field testing of the science materials used in the demonstration project improved general student performance, although investigation of eight programed versions did not indicate any adaptative features beyond that accounted for by individual pacing. Thus, it was decided to continue the evaluation of the programed materials as a complement to the demonstration project, and to incorporate adaptative procedures in the training program.

The continued evaluation of the programed materials made possible by the demonstration project are as follows.

a. The advantages claimed for basing science curriculums upon a structure of science and the heirarchial sequencing of concepts embodied in Gagne's task analysis suggested an investigation of the structure of the programed materials. Pyatte (55) defined the parameters of a structured unit and studied the influence of structured and unstructured measurement units, with laboratory activities, organized around the central theme, measurement as a valuable tool for science. Pyatte's recommended directions for research in the development of mathematical models to test hierarchies was presented at the 1968 Annual Meeting of the American Educational Research Association.

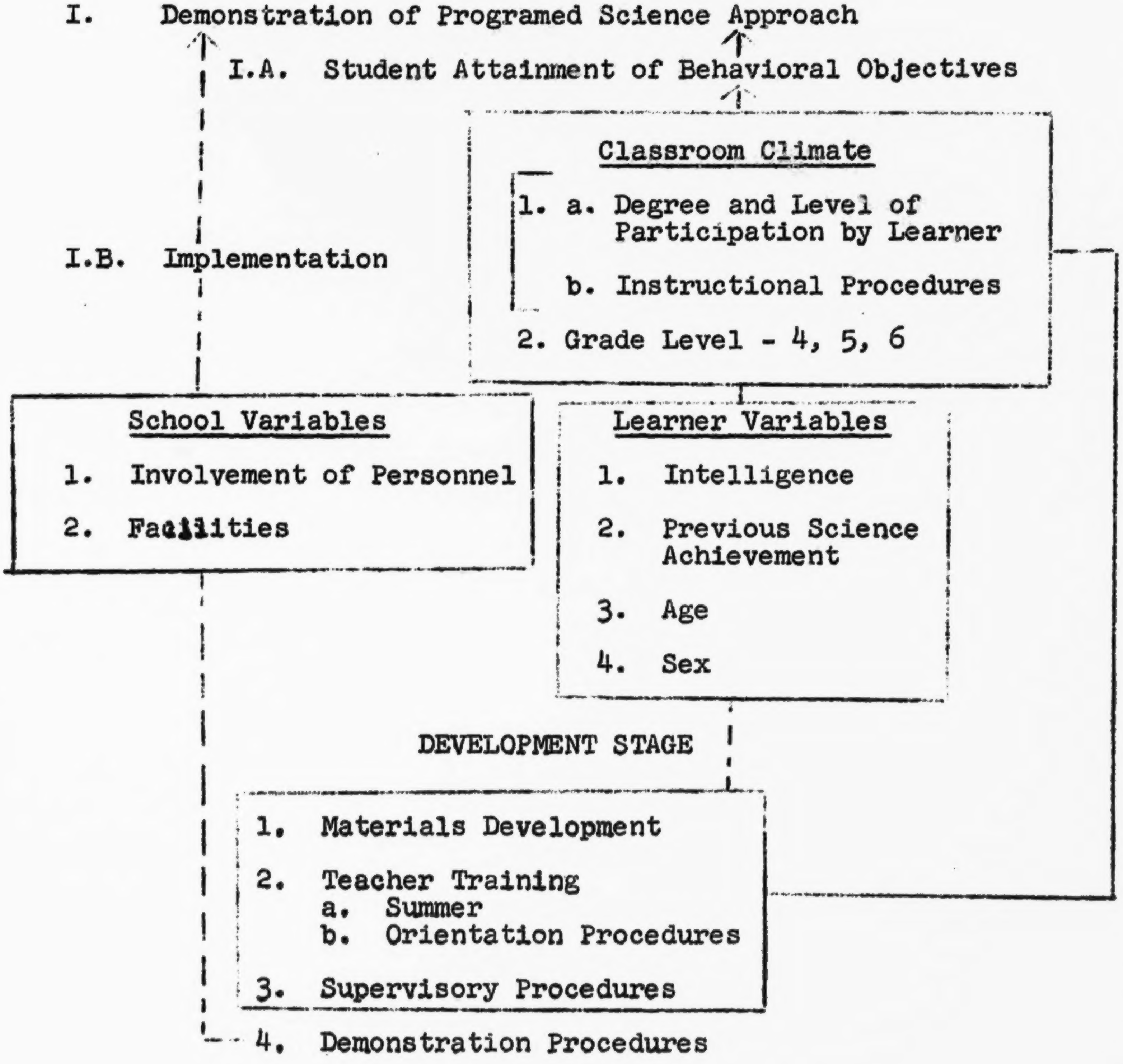
b. The integration of the individual student performance of laboratory activities with the programed materials has been demonstrated as a highly desirable program feature. Donaldson (16) continued investigation of the laboratory activities by examining the possibility of using a knowledge of the student's ability and personality adjustment to prescribe a method of experimentation that would better meet the expectations of the student. The three modes of experimentation observed the effects of placement and interaction with the teacher.

c. Research studies tend to agree that reading difficulty is an important criterion for selecting textual materials, and this variable is even more crucial to the students' success in using programed materials. Despite the apparent relationship between reading difficulty and self-instructional materials, readability has largely been ignored in the study of programed learning. The significance of the reading factor and the absence of a formula or method adapted to the programed approach prompted a pilot study in the Bureau of Educational Research (62), (40), to develop and implement an automated procedure to evaluate the readability of programed materials. The student responses were gathered from three units of the programed science materials and 18 independent variables descriptive of frame, response and presentation characteristics were related to student error rate and achievement criteria.

The findings of these studies will be discussed in relationship with the presentation of the procedures and conclusions of the demonstration project.

2. A paucity of the research in programed instruction is concerned with the training and instructional procedures which are effective in adapting programed materials to the educational program. Programed research in science education is primarily involved with the development of scientific units at the secondary and college levels. A technology of science instruction at the elementary level emphasizes the use of media, and not the media integrated within an organized instructional program. The role of the teacher in the traditional science program, as well as the nature and extent of the relationships between teacher characteristics and the objectives of the new curricula is largely unexplored. In order to observe the elements of the demonstration project within a comprehensive framework, the outline of a systems approach to instruction was selected to guide in the design, development, and evaluation of the demonstration project. An outline of the characteristics observed under each of the three stages serves to summarize the relationships observed by the demonstration project.

DESIGN STAGE*



I. Demonstration of Programed Science Approach

I.A. Student Attainment of Behavioral Objectives

Classroom Climate

1. a. Degree and Level of Participation by Learner
   b. Instructional Procedures
2. Grade Level - 4, 5, 6

I.B. Implementation

School Variables

1. Involvement of Personnel
2. Facilities

Learner Variables

1. Intelligence
2. Previous Science Achievement
3. Age
4. Sex

DEVELOPMENT STAGE

1. Materials Development
2. Teacher Training
   a. Summer
   b. Orientation Procedures
3. Supervisory Procedures
4. Demonstration Procedures

EVALUATION STAGE

I. Demonstration - Primary Goal

I.A. and I.B. - Secondary Goals

The unbroken lines represent an objective analysis of relationships; the broken lines, a subjective analysis.

*Outline presented by Saettler (59).

III

METHODS AND PROCEDURES

Presented in Chapter III is a description of the programed materials, the chronology of steps undertaken to accomplish the objectives of the demonstration project, participants, data collection, and the methods of evaluation.

I. PROCEDURAL STEPS

The contract was awarded June 1, 1966. Preliminary to this date, science materials were prepared for a summer course for elementary school teachers. The materials included three volumes of programed science materials, coupled with the individual student performance of experiments, a teachers handbook, and the necessary laboratory equipment. The programed materials typically follow a logical presentation, small-step, linear structure with constructed responses. The number of frames and laboratory experiments related to each unit is as follows:

Unit	Number Frames	Number Laboratory Activities
Volume I		
Introduction	23	
Sound	200	7
Light	314	6
Heat	287	4
Volume II		
Science and Its Ways	133	3
Measurement	309	7
Plants and Animals	322	7
Land, Water, and Air	135	4
Volume III		
Weather	172	16
The Earth and the Sun	259	7
Plants and Animals Living Together	247	13

Throughout each unit are subtests of about two - five items and an answer sheet for the student's use in checking his progress. At the back of each volume is a science dictionary. The programed text directs the student's progress throughout each unit. At the end of the unit he is instructed to obtain a unit test from the teacher. This test is graded by the teacher; and as a result of the student's test performance, he is either advised to proceed or devote additional time to the unit.

The Teacher's Handbook contains some hints on program procedures, a summary of each laboratory activity (the concept of the experiment stated as a behavioral objective, a procedural summary, and the necessary materials), a reproduction of the experiment sheet in the programed text, the unit tests and answer keys. A checklist of laboratory materials is also summarized for each of the three volumes.

A delay in final contract arrangements to June 1, left a short span of time between the selection of participants and the summer course of study. The response to the communications with science supervisors and superintendents in Virginia revealed a strong interest in the project, but teacher plans were generally fixed. It was anticipated that the summer course would just involve project participants; however only four members of the class were in a position to continue with the project.

Summer Program. The summer course was taught in cooperation with Dr. Ertle Thompson, Director of Science Education, University of Virginia, and Dr. Jeff Pyatte, Assistant Professor of Education. The entire class endorsed the use of the programed materials for study in the course. The class was introduced to the rationale of programing, and progressed through the materials, responding to the frames, performing the experiments, and taking the unit tests. The class members responded very favorably to this approach; the secondary teachers and supervisory personnel enrolled in the course felt they had gained a greater insight into elementary science and offered valuable contributions to class discussions. The elementary teachers became closely involved with the learning experiences of the student. Their criticisms of the materials indicated a good understanding of the approach and content. It was concluded that the materials were beneficial in the following ways: (1) the science units covered physical and biological sciences and did not require a strong background in science to grasp concepts, (2) teachers came to handle the laboratory activities with assurance and facility, (3) laboratory experiments, integrated with the text and concept development, gained a greater sense of purpose or meaning, (4) by progressing through a program in much the same manner as a pupil, the teachers became sensitive to learning problems and related methodology and scientific content to the behavioral objectives, and (5) the transfer effects of both instructional procedures and scientific content appeared high. The teacher criticisms of the programed texts were incorporated before the materials were distributed to the student population in the fall.

September, 1966. Twenty-four classes from the school districts: Nelson, Albemarle, Henrico, and Bland Counties; Chesapeake, Waynesboro and Martinsville Cities participated in the project. Eight fourth-grade classes, ten fifth-grade, five sixth-grade, and one combined class were included in the study. The school divisions are representative of rural, suburban, and urban areas. The number of divisions was limited because of the supervisory assistance designed as a follow-up to the orientation sessions.

The purpose of initial contact with the school divisions was to briefly introduce the materials for an assessment before a decision was reached to participate in the project. All schools elected to use the materials, and orientation classes were scheduled in each division. Teachers, principals, supervisors, and in some instances, superintendents attended the orientation sessions. The meetings focused on the results of the background studies and the instructional procedures involved in such an approach. Personnel were allowed at least one month for study of materials before the initiation of the project in the classrooms. During this time the scheduling of classes and the allocation of experimental materials and programed texts was accomplished. Classes were scheduled to meet one-half to three-quarters of an hour per day, varying from either two days (if longer periods) to five days a week.

November, 1966 - June, 1967. Two faculty members and six graduate assistants, each averaging two days per week at each school (one day for schools farther away) supervised the study. Supervisory responsibilities included instructing teachers in the effective use of materials and experiments, setting up science experiments, assisting in grading tests and other classroom duties. As the project continued, effort was made to phase out concrete assistance and to serve in a consultant capacity.

The schedules and use of the programed materials varied. The teachers were allowed flexibility in supplementing the programed materials; however, all teachers used the materials as the major part of the curriculum.

The demonstration of the programed approach to science varied widely among schools. The Science supervisors remained heavily involved in the project throughout its duration. They assumed a major responsibility in the coordination and distribution of materials and equipment, were frequent observers, and provided close assistance to the teachers. In districts without a Science supervisor, the elementary or general supervisor and/or principal assumed the role of instructional leader. Some principals were instrumental in effective community relations. Teachers communicated within each of the schools, and in some schools students outside the project shared the use of equipment and laboratory experiments with the project classes.

The data collection was as follows:

1. intelligence - Lorge-Thorndike

2. pretesting of science achievement

    a. STEP Science Achievement test
    b. True-False Test

Students were randomly assigned Form A or Form B of the STEP Science Test for pretesting and received the alternate form in the post-testing situation. The True-False Test was developed and validated in previous studies (33) with programed materials. The test represents a more factual and closely related measure to the materials than does the STEP Test.

3. age of student (in months) was obtained in October

4. sex of student

5. grade of student - 4, 5, or 6

6. rating of classroom climate - a checklist of eight student behaviors (see Appendix A) was abstracted from observations of background studies; a checklist of eight comparable behaviors describing instructional procedures was also prepared. Supervisors recorded observations during the project, and at the end of the school year, teachers were asked to rate the student behavior of their respective classrooms, relate any critical incidents, document observations, and comment on supervisory assistance.

7. the scores of nine unit tests -(validity and reliability determined in background research)

8. post testing - True-False Test
   STEP Science Achievement Test

Summer, 1967. A two-day evaluation conference was held in August. The first day was spent in a discussion and evaluation of the use of the programed materials. The following day was devoted to a presentation of some of the newer developments in science. Eighteen teachers, fifteen supervisors and administrators, and four members of the Virginia State Department of Education attended the conference. A copy of the program is attached (See Appendix B).

Related Studies

Concurrent with the demonstration Pyatte (55) studied the influence of structure on the measurement unit in Volume II of the materials. Three fourth, two fifth, and two sixth grade classes involved in the project were selected for this study. The Iowa Tests of Basic Skills, Lorge-Thorndike intelligence scores, and arithmetic test, sub-achievement tests after each of the four measurement heirarchies, and a transfer test comprised the data for the study. The pattern of correlations between basic ability and sub-achievement measures satisfied the assumptions for the structured and unstructured units. The data were analyzed using 3 x 3 x 2 factorial analysis of variance mixed model with basic ability and mode of unit fixed. The findings showed the mode of unit was an important factor only for students of high basic ability (these students' performance was relatively higher using the structured unit), basic ability is significantly related to achievement and transfer, and suggest older students are more successful in transfer. Pyatte's analysis of structure has direct implications for the evaluation of the effectiveness of the remaining science units.

After the 9-month demonstration period, Shaw (62) gathered the response data from the units on sound, light, and heat, and the intelligence, and achievement data of these students. The purpose of the study was to automate a procedure which could be used to determine the reading difficulty of the fourth-grade programed science materials. Seventeen independent variables descriptive of the structure, organization, and density of mathematical and scientific terms were defined. A computer program was developed to automate counting the variables and relating the independent variables to the criterion, error rate. Error rate was validated against achievement and intelligence measures, and a regression analysis procedure was determined to establish a readability equation. Three independent variables, the average number of mathematical and scientific words per sample, per cent of response frames per sample, and average number of review frames were identified as best predictors of error rate. This study is being expanded to identify those variables which influence reading difficulty in each unit, differences among programers, and the related influences of branching techniques.

September - June, 1967. As a result of the demonstration project and follow-up conference, requests to continue or initiate this approach were received from participating and non-participating school divisions. However, the dissemination of materials was limited because of funds, books, and available supervisory assistance. However, teachers familiar with the program and minor additions of new teaching situations were possible. Three classes in Waynesboro, two classes in Nelson County, and one class each in Henrico County, Richmond City, and Chesapeake were selected to continue with the program. The principal, science supervisor, and teachers in the Richmond school drew on the experience of the Henrico classroom; several other school systems utilized the materials in local curriculum studies of elementary science. The classes in the Nelson County and Waynesboro school divisions were involved in an experiment described below.

Donaldson's (16) major question under investigation was: Should educators consider using levels of basic ability, intelligence and personality adjustment as factors in the assignment of mode of experimentation in which achievement is the evaluation criterion? One hundred forty-six students were randomly assigned to one of three modes of experimentation: Method I - experiments placed preceding textbook discussion as an introduction to the concept; Method II - Teacher-Pupil Interaction, where student directed to teacher to engage in a discourse which outlines specific aspects of the experiment; Method III - Non-Interaction Method - student receives the same direction, but in a different format through written questions similar to those outlined for teacher discourse in Method II.

Unit tests on sound, light, and heat were defined as measures of achievement, basic ability was measured by the Iowa Tests of Basic Skills, intelligence by the Lorge-Thorndike Intelligence Test, and personality adjustment by the California Test of Personality. Among Donaldson's conclusions are the suggested relationships between mode of experimentation and student characteristics, basic ability and personality adjustment. For students of high level basic ability and high level personality adjustment, the method of experimentation is of little consequence; for students of high basic ability and middle level personality adjustment, a logical choice of methods is to provide written direction; for the student of middle level basic ability and low level personality adjustment, a teacher-oriented approach with directed verbal interaction is indicated as a more effective approach; and for persons of low level basic ability and low level personality adjustment, it is likely that the method of performing experiments contributes little effective influence in determining achievement gain.

II. EVALUATION

Design

Major Goal I Demonstration of the programed approach in teaching science at the upper elementary school levels.

It is assumed that the demonstration of this instructional approach is related to the two secondary goals:

IA Implementation of the programed approach: the criterion - X_1, classroom climate

IB Student attainment of Behavioral Objectives: criterion measures - STEP and True-False Science Achievement and unit tests

Variables which describe the instructional design are:

Classroom climate	X_1.	degree and level of participation by learner and nature of instructional procedures
	X_2.	grade level - 4, 5, 6
Learner variables	X_3.	intelligence
	X_4.	previous knowledge of science - pre-testing, STEP Science Achievement Test
	X_5.	previous knowledge of science - pre-testing, True-False Test
	X_6.	age of student
	X_7.	sex of student
School variables	8.	involvement of personnel
	9.	facilities

Development

1. Materials development. The evaluation of programed materials was accomplished in background studies. The Teacher Handbook was prepared for summer training and fall orientation.

2. Teacher Training. The summer program involved the study of the programed materials, coupled with laboratory experiences, a presentation of the rationale of programing and discussion of instructional techniques.

The orientation sessions introduced superintendents, principals, supervisors and teachers to background studies, the purposes of the demonstration project, and the nature of the programed approach. In-service training was accomplished through supervisory procedures.

3. Supervisory procedures. Two faculty members and 6 graduate students were responsible for the supervision of the 24 classes. Training sessions were held for those students not familiar with the classroom application. The supervisory responsibilities of these students were initially carried out as a team with an experienced person. Each supervisor assumed the primary responsibility to coordinate and administer the program in a given set of classes. Throughout the year, supervisors were generally rotated to several classroom situations to counterbalance bias in supervision and to present a broader range of experience.

4. Demonstration procedures. The involvement of supervisory and administrative school personnel was initiated by each school division. Dissemination throughout the State was encouraged by the Summer Evaluation Conference, and assistance to follow-up studies during 1967-68. Continuing efforts focus on training and coordination with the Virginia State Department of Education.

Evaluation

Implementation of the Approach - Secondary Goal. Two questions are central to this part of the evaluation: (1) To what extent has the programed approach been successfully implemented, and (2) What is the relationship of the implementation to the developmental stage (materials, training, supervisory and demonstration procedures)?

Implementation is defined by X_1 - classroom climate, degree and level of participation by learner and nature of the instructional procedures. A checklist of pupil behaviors (Appendix A) and related instructional procedures were developed from the rationale of the programed approach and previous observations of programed classes. The eight items of pupil behavior include measures of student attitude and cooperation, the students ability to follow the organizational procedures, and the students interaction with the content.

The instructional procedures are marked by a shift in the control and responsibility for learning to the individual student, guided by the teacher within an organized classroom situation. Instructional techniques must recognize respect and understanding in instructor-pupil relationships, familiarity with wide range of materials and experiments, testing procedures as diagnostic, and organizational procedures which balance instructional adaptations with the self-instructional, individually paced features of the program.

Teacher observations, criticisms, and supervisory ratings describe the nature and extent of the implementation and the observation of implementation practices with school variables (facilities and personnel involvement) identifies varying conditions. The relationship of the observations of the classroom climate to the developmental stage is subjectively analyzed and indicates the degree of success attributed to the materials development and accomplished by the training, supervisory and demonstration procedures.

Student Attainment of Behavioral Objectives - Secondary Goal. Student attainment is measured by final STEP and True-False Science Achievement tests and eight unit tests. A multivariable analysis is used to relate X_1, three levels of classroom climate (mean of supervisory ratings of pupil behavior and instructional procuedres for each class is classified into upper, middle and lower thirds); X_2, grade level - 4, 5, 6, X_3 - intelligence, X_4 and X_5, initial knowledge of science, X_6, age of student; and X_7, sex of student to the criterion measures of science achievement. The analysis relates the degree of successful implementation to a study of the influence of learner variables on student achievement, and, as such, provides some empirical evidence to support the relationships proposed between the secondary goals - Implementation and Student Attainment, and the developmental stage (materials, training, supervisory and demonstration procedures).

A multiple regression technique (5) of the form $Y = a_1X_1 + \ldots a_7X_7 + K$, where the X's are the values of the independent variables, and the a's are the regression coefficients, and the K is the constant for the equation, will be used to test the null hypothesis of the form:

X_i (where i = 1, 2, 3, ... 7) does not contribute to the regression equation to predict the True-False achievement; STEP science achievement; the achievement of 8 unit tests ($a_i = 0$).

The F-ratio statistic, .01 level of significance is utilized to establish the rejection or acceptance of the null hypotheses (ratio of regression means square to residual mean square).

Primary Goal - Demonstration of Programed Approach. Successful teacher implementation and student attainment of course objectives are crucial to the demonstration of the programed approach. The evaulation of the demonstration potential will first observe the set of relationships defined by the objectives, implementation and student attainment, and next appraise the dissemination activities undertaken by the project.

CHAPTER IV

ANALYSIS AND FINDINGS

Chapter IV presents the analysis and findings of the two secondary goals, Implementation of the Programed Approach and Student Attainment of Behavioral Objectives, the evaluation of the primary goal, the Demonstration of the Programed Approach, and concludes with a discussion of the implications of the design evaluation on the developmental stages (materials, training, supervision, and demonstration procedures).

I. IMPLEMENTATION OF PROGRAMED APPROACH

A subjective evaluation of the implementation of the programed approach in the classroom draws on teacher observations of pupil behavior, her criticism of this approach and an appraisal of supervisory assistance. The supervisor's observation of pupil behavior and related instructional procedures provides a general indication of the agreement with teacher comments and of the effectiveness of the supervisory assistance provided to the teacher.

At the close of the experimental period (June, 1967), each teacher was asked to approximate the typical classroom behavior on a seven point scale for each of eight items descriptive of pupil behavior using the programed approach and to document observations. Directions were given to check the first blank if the item referred to nearly all her students; the second, if the item referred to most students; the third, if item described slightly more than 1/2; the fourth, if item referred to about 1/2 of the pupils. The first three blanks are identified as 7, 6, 5, and indicate a positive tendency, blank 4 is the midpoint or average tendency, and blanks 3, 2, 1 indicate a "slightly greater-than," "most," or "nearly-all" description of classroom behavior associated with the negative counterpart.

Student's Attitude Toward the Programed Approach. The general reaction and cooperation of pupils involved in the project were observed using scales Nos. 7 and 8:

7.	Responded eagerly to begin work in science ...	vs.	Made rude remarks, quarrelsome, whispered, wandered about ...
8.	Paid close attention to teacher or supervisor	vs.	Were slow in responding to teacher's or supervisor's requests

Teachers rated their classroom high on these two points, typically a 6 or 7, and no rating was reported falling below the midpoint. Most teachers described the students' attitude as one of eager anticipation, attention, and enjoyment. One teacher reported a drop in the interest level, and attributed it to the low reading ability of the class.

Student's Understanding of and Relationship to Program Procedures. Item No. 4 provided a measure of the student's understanding of this approach:

4.	Students were aware of this approach ... understood leaving text ... etc.	vs.	Excessive guidance at the experiment table or with the program procedures

Teachers rated Item 4 high, typically indicating a 6 response - most students followed the order of textual, experimental, and testing activities independently.

Items 5 and 6 checked two specific instances of the pupils' work habits and the programed approach:

5.	Found own learning rate, ... using cover sheets, no competition or rushing ...	vs.	Proceeded too fast ... pretended to work, copied answers
6.	Reviewed for unit test and/or received criticism of results well	vs.	Asked other students for help ... showed little interest in test results

The typical teacher response to items 5 and 6 was a 5, or they generally felt that slightly greater than 1/2 of their students had positive work habits toward use of book and unit tests. Some teachers reported that slow readers were more likely to rush through the material. Some observed students who did not effectively use unit tests to assist in a review of missed concepts; time was not always available to personally guide each student's behavior after his subtest.

Relationship of Student's Behavior to the Programed Content. Items 1, 2, and 3 observe student behavior and the programed and laboratory content:

1.	Read programed text with little sign of attention wandering	vs.	Were restless, gazed about ... wasted time at desks
2.	Performed experiments with little confusion, chatter, etc.	vs.	Loitered over exp. table or sheer play ...
3.	Evidenced understanding of the purpose of the experiment, became science minded ...	vs.	Reluctant to ask questions or inhibited at the experiment table

Typically, teachers placed their classroom behavior in the 6-5 range, slightly more than 1/2 or most students responded positively to items 1 and 2. Teachers' responses to item 3 covered a wide range, 4 or the midpoint representing an average response.

Comments from teachers regarding the content of the materials included "well organized," "stimulating," or "activities created interest," and "helped slower readers to understand." Negative comments cited a difficult vocabulary for some children or "readability" problems, and "students did not always gain concept from the experiment." Self pacing was not always considered sufficient to individualize instruction either for the poor reader or for the higher ability child.

Teachers suggested more teacher-student interaction centered on experiments, a mixture of learning methods in which temporary student groups might be formed to discuss major concepts, and/or student performance of more experiments which apply to the same concept. The use of student experiment sheets to be checked by the teacher was also suggested to emphasize the purpose of the laboratory activities. One teacher suggested adjusting the difficulty level of the text, others, the vocabulary level.

Teacher adaptations or devaitions from the programed approach were not extensive. However, some teachers introduced vocabulary drills, give teacher-demonstrations of the activities, or utilized the assitance of the faster students at the experiment table. Less frequently, class projects connected with the units were introduced as a basis of class discussion, and/or students proceeding at a faster rate initiated class activities which were completed as the remainder of the class progressed through the unit.

In summary, teachers felt that the programed appraoch was a profitable experience for the pupils, although some students did not gain a full comprehension of the materials. The students' attitude toward studying science using the programed approach was generally reported as highly enthusiastic; the approach created no difficulty for nearly all students. Two major suggestions were to adjust the readability and key in verbal reinforcement to the laboratory activities through teacher or student interactions.

The supervisors' observations of pupil behavior was in general agreement with those of the teachers. The percentage of responses for eight items indicates a generally positive recording of student behavior:

Positive Observation	10%	30%	20%	18%	12%	8%	1%	Negative Observation
	7	6	5	4	3	2	1	

The highest ratings were given to measures of students' attitudes (item 7 and 8) and students' understanding of the program procedures (item 4). The ranking of these items corresponding to the teachers' evaluations. At least 60% of supervisory rating of items 1, 2 and 5 fall above the midpoint-4; and at least 50% of the ratings of items 3 and 6 fall in the positive range above the midpoint. The supervisors' ralatively low rankings of item 3 (understanding of the purpose of the experiment) and item 6 (review and criticism of unit tests) are in agreement with teacher ratings.

Supervisory observations of instructional procedures were generally positive. The percentage of observations falling along the scale for the 8 items are summarized as follows:

Positive Observation	11%	28%	16%	14%	13%	12%	6%	Negative Observation
	7	6	5	4	3	2	1	

Two scales describing classroom and pupil relationships (scale of respect for opinion, patient, sympathetic pupil relationship) were observed as positive in most cases. Next in rank were items relating to teacher attitude toward the approach and her increasing independence, over 50% of responses falling above the midpoint in the positive range. Observations related to the interpretation and use of test results and organizational procedures followed with approximately 50% of the responses in the positive range (7-5). Familiarity with materials and planning ahead for experiments fell about 50-50 above and below the mid-score.

School-Related Variables

Facilities. Classroom and storage space presented a problem in several instances. As the spread among pupils increased, a larger area was needed to set up laboratory experiments. In addition, water and sinks were not available in every classroom. Crowded classrooms (the number of students approaching 30 or over) added to the space problem. Those teachers working under crowded conditions were presented with more difficulties in setting up and spacing experimental activities; however, some teachers reported that despite the additional problems created by lack of space, they felt that they had successfully compensated for this problem. Classroom observations tend to support this observation.

Personnel. The superintendent was instrumental in either selecting or providing a list of possible classes, involving the appropriate supervisory and administrative personnel, and setting up orientation sessions.

Elementary, general and/or science supervisors participated in the orientation sessions, and became involved through observation and/or direct assistance. The science supervisors were particularily involved in the location and distribution of equipment, setting up experiments, offering direct assistance to the teachers and coordinating the project with the university. The role of the principal varied from that of an instructional leader, offering assistance to the teachers and drawing on the science equipment in the school, to educating the parents and community, and to the related concerns of sequencing, organization and grading practices.

In summary, it appears from teacher and supervisory observations that the implementation of the programed materials was effective for the following reasons: (1) students and teachers were enthusiastic and/or favorable towards this approach, (2) students followed the programed procedures with minimum of direction, (3) over 50% - most students concentrated on reading the programed text and performed experiments with little confusion, (4) a courteous, patient and sympathetic atmosphere typically prevailed in the classrooms (5) teachers became increasingly independent, (6) those organizational features (students' learning rate, unit test procedures, instructional planning and control) and student understanding of the purpose of the experiment which were given a relatively lower rating than the other items reflected, nonetheless, a positive tendency, and (7) supervisory and administrative involvement was cooperative and effective.

II. STUDENT ATTAINMENT OF BEHAVIORAL OBJECTIVES

The criterion measures of student attainment of behavioral objectives are defined as post-test achievement, STEP Science Achievement Test and a True-False test developed by the Bureau of Educational Research, and the scores on eight unit tests, each administered after the completion of the respective unit.

The data are presented and analyzed by two groups; the complete group, N = 369, is comprised of students who completed the three volumes of programed materials by the post-testing dates in May, 1967, and the incomplete group, N = 328, includes those students who did not complete the programed materials. Tables I and II present the means and standard deviations of selected student characteristics of each group and the intercorrelations among the variables. It can be noted from Table I that the complete group is of average intelligence and scores higher on the average on intelligence and achievement testing than does the incomplete group. The average age of the incomplete group is about one year older than the mean age of the complete group.

Table II shows that intercorrelations among the intelligence achievement measures for both groups are significant and positive, the STEP test more strongly related to intelligence than the True-False test. No significant relationship exists between age and achievement measures for the complete group; significant negative correlations are present for the incomplete group. A significant negative correlation is found between age and intelligence for both groups. In general, older pupils in the incomplete group will tend to have lower intelligence and achievement scores, and students with higher intelligence scores can be expected to demonstrate greater initial and final science achievement.

The percentage of boys and girls is nearly the same in each group; i.e., for the complete group the percentage of boys = 50.6 and girls = 49.3, for the incomplete group percentage of boys = 50.3, girls = 49.6.

The percentage of pupils falling within each level of classroom climate (Level I, highest; Level II, average, Level III, ranked third) and within each of the three grade levels is as follows:

	Complete Group	Incomplete Group
Climate	percentage	percentage
I	40	31
II	51	46
III	9	23
Grade		
4	50	19
5	41	53
6	9	28

In general, the incomplete group contains a relatively greater number of sixth grade students; the relative classroom climate between the groups indicates a smaller proportion of students at Level I and a larger proportion in Level III for the incomplete group.

The study was intended to demonstrate the programed approach in above average fourth-grade classes, average fifth grade classes, and below average sixth grade classes. Table III indicates this tendency. The average intelligence drops for each grade in the incomplete group, although much less so for the fourth grade. In addition, students by grade in the incomplete group are older. The initial achievement for the 5th and 6th grade groups is higher in the complete group, but differences between the two groups at the 4th grade level are much closer and in the opposite direction. A greater initial knowledge of science can be observed for the 5th and 6th grade classes in the complete group. More gains in science achievement are present at all grade levels for both groups.

Presented below is the percentage of pupils by grade, level of classroom climate and complete vs. incomplete groups:

	Grade 4		Grade 5		Grade 6	
	Complete	Incomplete	Comp.	Incomp.	Comp.	Incomp.
Level I	29.5	5	56	20	23.5	70
Level II	60	95	35	36.6	76.5	29
Level III	10.4	0	9	43.4	0	0

The percentages indicate no direct relationship between grade level and classroom climate. Grade 6 students fall within Levels I or II and are largest proportion of students at Level I for the incomplete group, while grade 5 is generally

TABLE I

MEANS AND STANDARD DEVIATIONS OF STUDENT CHARACTERISTICS

Variable	Complete Group, N=369		Incomplete Group, N=328	
	Mean	SD	Mean	SD
Intelligence	101.91	14.91	89.49	15.45
Pre STEP	33.89	10.58	29.06	10.93
Pre True-False	114.20	17.90	111.10	15.64
Post STEP	37.17	10.62	31.33	10.79
Post True-False	131.58	17.23	122.04	21.35
Age (in months)	122.07	12.40	133.78	16.05

TABLE II

INTERCORRELATION MATRIX OF CONTINUOUS MEASURES - COMPLETE AND INCOMPLETE GROUPS*

	Pre STEP	Pre T-F	Post STEP	Post T-F	Age
Intelligence	.61(.66)	.39(.43)	.61(.64)	.51(.43)	-.46(-.61)
Pre STEP		.55(.60)	.74(.75)	.66(.55)	-.06(-.26)
Pre True-False			.57(.57)	.60(.50)	.02(-.18)
Post STEP				.74(.61)	-.08(-.31)
Post True-False					-.04(-.19)

*Intercorrelations outside parentheses, complete group
inside parentheses, incomplete group

TABLE III

MEANS AND STANDARD DEVIATIONS OF STUDENT CHARACTERISTICS SORTED BY GRADE LEVEL

Complete Group

	Grade 4		Grade 5		Grade 6	
	N=183		N=152		N=34	
	Mean	SD	Mean	SD	Mean	SD
Intelligence	104.92	15.79	100.73	12.92	90.88	12.23
Pre STEP	31.49	10.43	36.61	9.92	34.64	11.13
Pre True-False	112.36	18.30	115.24	17.35	119.38	16.71
Post STEP	35.51	10.99	39.19	9.82	37.00	10.44
Post True-False	128.41	18.05	134.80	16.03	134.21	14.68
Age	113.81	8.22	127.36	7.79	142.82	10.47

Incomplete Group

	Grade 4		Grade 5		Grade 6	
	N=62		N=175		N=91	
	Mean	SD	Mean	SD	Mean	SD
Intelligence	102.76	16.75	88.62	14.18	82.13	10.38
Pre STEP	32.98	12.26	27.40	10.71	29.58	9.56
Pre True-False	116.53	15.65	107.82	15.59	113.71	14.13
Post STEP	35.74	11.35	29.84	10.62	31.19	9.87
Post True-False	129.42	18.60	118.34	21.46	124.15	21.29
Age	115.13	9.07	133.05	12.31	147.89	11.94

associated with Level III for this group.

The percentages presented by level of classroom climate and grade level likewise indicate no straight forward relationship between the two variables:

	Level I			Level II			Level III		
Grade	4	5	6	4	5	6	4	5	6
incomplete	3	34	63	39	42	18	0	100	0
complete	36	57	6	58	28	30	57.5	42.4	0

Thus, the presentation of descriptive data indicates that grade level (and age) are inversely related to intelligence measures, the greater mean age for the incomplete group is at least in part attributed to a relatively greater number of 6th graders. 5th and 6th graders in the complete group tend to score higher in initial achievement and maintain post-achievement gains over the fourth grade at post-testing. 4th graders of relatively higher ability tend not to complete the program and score higher in initial and final science achievement than the fifth and sixth grade incomplete groups. Neither grade level nor completion of program appears to have a direct influence on the observations of pupil behavior and instructional procedures which identify classroom climate.

Relationships among classroom, teacher and criterion variables

A multivariate analysis was used to establish the set of relationships between the dependent variables (classroom and learner characteristics) and the criterion measures of science achievement. The dependent variables included in the analysis were:

Classroom climate - Levels I, II, III
Grade - 4, 5, 6
Intelligence scores
Pre-testing: STEP Science
True-False test
Student age in months
Sex of student

Separate analyses were run for the complete and incomplete groups against (1) Post-STEP Achievement, and (2) Post-True-False achievement. Eight analyses were run for the complete group, unit tests defined as the criterion measures.

A key to the variables analyzed by the multivariate analyses is presented in Appendix C; the rationale for the analyses, taken from Bottenberg and Ward (5), is presented in Appendix D.

The generating procedure considered the concomitant effects of (A) Levels of Classroom Climate and I.Q., Pre-STEP, and Pre-True-False, (B) Grade levels and I.Q., (C) Sex and I.Q., Pre-STEP, Pre-True-False, and age, vs. Post-STEP and Post-True-False for the complete and incomplete groups. The generating procedure for tests of hypotheses, check for the tests and results of tests are summarized in Appendix E. No test reached the .01 level of significance, although the level was approach in four instances:

Incomplete group

dependent variable		dependent variable	Classroom
4	sex and age	5	Climate and Pre-STEP
		5	Sex and I.Q.

Complete group

4	sex and pre-STEP		

The generating procedure and check for comparing treatment effects when a concomitant variable may be operative is presented in Appendix F. Covarying age, pre-STEP and I.Q. scores slightly reduced concomitant variance in three models; the inter-group mean differences between levels of classroom climate and pre-STEP vs. post-true-false for the incomplete group reached the .01 level.

A summary of the final data analysis is presented in Tables IV and V, Appendix G. The results of the analyses of the complete group (Table IV) indicated that relative to the model of independent variables - I.Q., pre-true-false, age, sex, classroom climate and pre-STEP (control variable) that intelligence significantly influenced post-STEP achievement beyond .001 level, and age, sex and climate did not show a significant influence. Relative to the model of independent variables - I.Q., pre-STEP, pre True-False, age, sex, classroom climate, the same results held for the dependent variable, post True-False science achievement.

The incomplete group analysis (Appendix G, Table V), independent variables - I.Q., pre-STEP, pre True-False, age (control variable), sex, and classroom climate - deleted intelligence, pre-STEP, pre True-False, sex, and classroom climate and observed influence on the dependent variable, post-STEP Science Achievement. The variables significant at or beyond .001 level were intelligence, pre-STEP, pre True-False, and classroom climate. A secondary analysis which considered the effects of age and sex by checking age with sex excluded from the model also found age to have no significant influence on post-STEP achievement. The models relative to post True-False achievement did not indicate a significant influence attributable to age, sex, or teacher climate.

Table VI, Appendix H, summarizes the multivariate analyses, complete group, between the model - sex, pre-STEP, pre true-False, age, classroom climate, repeated for eight unit tests, and checked for the influence of I.Q., age, sex, and classroom climate. In all instances the influence of I.Q. reached beyond the .01 level. In only two other instances was a significant influence observed beyond the .01 level; levels of classroom climate influenced the light test and age significantly influenced the unit test on plants and animals. The data reveal no explanation for these two results. The light test correlates higher with intelligence than any other test and higher mean achievement tends towards the lower levels of classroom climate; age is positively related to the unit test achievement on plants and animals. The light test is likely the most difficult; the plants and animals test, the longest. The highest possible score, the mean and standard deviation for each of the unit tests is presented in Table VII, Appendix I.

A summary of the influence of the dependent variables is presented below:

Intelligence. The measured intelligence of upper elementary students significantly influences the final science achievement as measured by the STEP Science Achievement Test, the True-False Science Achievement Test, and the 8 unit tests. A significant positive relationship exists between pre- and post achievement measures and intelligence. The correlation between I.Q. and STEP achievement is relatively higher than the relationship with the True-False test.

Initial Science Achievement. The STEP Science Achievement Test and the True-False Test were administered at the initiation of the demonstration project. Both measures are significantly related to final achievement.

Maturity. Maturity is observed by the age and grade of student. The significantly negative correlations between age and intelligence (Table II) and the means sorted by grade (Table III) indicate an inverse relationship between ability and age. This relationship fulfills the intent of the study, to demonstrate this approach with lower ability sixth graders, average ability fifth graders, and above average fourth graders, although higher mean intelligence would have been more desirable for those fourth grade classes falling below average. Maturity did not significantly influence the final science achievement (for either the complete or incomplete groups) relative to the influence accounted for by intelligence, and prior knowledge of science. Mean gains in achievement at all grade levels for the incomplete and complete groups and the insignificant influence of maturity relative to model of independent variables suggests the use of the programed approach is beneficial at the three grade levels.

Sex. Sex did not generally influence the final achievement, but intergroup mean differences with sex as a variable approached the .01 level. Table VII, Appendix J, indicates the relatively higher intelligence, pre-STEP achievement and lower age for girls is not proportional to the mean differences in final science achievement. The boys tend to perform at a relatively higher level.

Classroom Climate. The mean student characteristics, sorted by the three levels of classroom climate, are presented in Table IX, Appendix J. Classroom climate did not influence the complete group; however, the data suggest that for the incomplete group or for students of below average ability, the classroom climate has a significant influence on final science achievement. For the incomplete group, concomitant variation can be observed between classroom climate and Pre-STEP vs. final True-False achievement where,, Pre-Test achievement with a higher classification of classroom climate is associated with relatively higher final True-False science achievement. The levels of classroom climate significantly influence final STEP achievement. Despite relatively low mean I.Q.s, an equal or greater STEP science achievement occurs with relatively higher ratings of classroom climate. The data suggest that the pupil behavior and/or instructional procedures observed as a measure of classroom climate may compensate for relatively low ability levels, either directly, or as a manifestation of a learner or instructional variable; e.g., age.

III. DEMONSTRATION OF PROGRAMED APPROACH

The successful implementation and related student achievement contributed to a sustained interest in the project; the continued involvement of local supervisory and administrative personnel in turn provided valuable assistance to the operational stage. After the fall orientation sessions, each school division initiated the participation of supervisory and administrative personnel. No one pattern of operation describes the participation in the project. However, some general observations of the nature of the involvement are as follows:

1. Supervisors. Where a division employed a science supervisor, his participation was extremely useful in ordering, locating, and setting up laboratory experiments. The participation of all supervisors included observation, teacher assistance and coordination from the university.

2. Principals. The principals' initial assistance involved scheduling classes and locating equipment within the schools. Their activities included coordination of demonstrations with personnel outside the school and/or the community maintained contact with the university, and assisted with related practices (e.g. grading, facilities) and individual teacher problems.

3. Teachers. The participating teachers shared experiences with other teachers in the school by demonstrating this approach and by involving other students in the experiments and demonstrations.

The specific objectives of the system readily identify areas of supervisory or instructional assistance. The laboratory experiments, in particular, offer a specific means by which the supervisory or administrative can become involved in the elementary science program and the teacher can relate more closely to the facilities available in the school. By specifying the tasks, this approach lends itself to a variety of school situations, ranging from small, rural schools to suburban and city communities. Either a supervisor or school principal can effectively serve as an instructional leader.

The demonstration project was formally presented on a state-wide basis at a Follow-Up Conference, August 9-10, 1967. Program participants, science supervisors in the State and members of the Virginia State Department of Education were notified of the meeting. The conference had three major purposes: (1) a follow-up evaluation and discussion by participants, (2) the dissemination of information about the project, (3) a critical examination of elementary science programs. The topics of the conference are given in the copy of the program, Appendix B.

The outcomes of the demonstration project and follow-up conference are as follows:

1. The teachers in all school systems wished to continue with the program. Local funding and availability of materials limited participation in 1967-68 to 7 classes, and one new system. Several other new systems requested and obtained materials for curriculum studies. Teachers who had participated in the experiment kept samples of materials and handbooks as an adjunct to the elementary science program.

2. Coordination with the Virginia State Department of Education. Two members of the State Department observed the study during the 1966-67 demonstration period. As a result of the conference, it was suggested that the books be adopted by the State. This process has not as yet been formalized in order to incorporate revisions resulting from the demonstration project and related studies described below.

3. Studies by Pyatte (55), Shaw (62), and Donaldson (16) were made possible by the demonstration project. The teacher criticism of readability and a more effective use of the laboratory experiences emphasized the need for the development of a readability formula adapted to the programed approach and further investigation into the most effective use of the laboratory experience.

4. The programed materials have been adapted to the computer to evaluate the effectiveness of four programing approaches (49) and to adapt the automated feature of the system to a readability analysis of the materials and a model to evaluate

and define program structure. This phase of the investigation offers specific advantages to the rapid production and revision of materials, for the dissemination of programed texts adapted to ability levels, or dissemination through computer-assisted instruction.

5. Training. A course in instructional technology was introduced into the university, 1967-68. Slides, materials, and findings of the demonstration project will be fully utilized in the course.

IV. IMPLICATIONS FOR DEVELOPMENTAL STAGE

The relationship of the findings of the demonstration project in the developmental stage are summarized below:

Materials Development.

1. The materials are generally effective for fourth and fifth grade students of average and above ability and sixth grade students of lower ability. The students are highly motivated and show gains in achievement.

2. The teacher's recommendations to adjust the readability level are validated by the positive relationship between intelligence and achievement. The development of an automated readability analysis and its application to units identifies those frame, response, and content and presentation characteristics which are related to a high error rate and low achievement; hence, textual revisions can now be more effectively accomplished.

3. The more effective use of laboratory experiments was investigated in 1967-68. The investigation prescribed one of three experimental modes for students of varying personality and basic ability levels.

Training and Supervision.

1. Teachers' response to training and their facility in using this approach recommends the materials as an effective way to (1) introduce new scientific content into the elementary science program, (2) include the use of laboratory experiences in the science curriculum, (3) individualize instructional procedures and (4) involve supervisory and administrative personnel in the elementary science program.

Teacher and supervisory observations recommend (1) that instructional procedures be more fully developed which suggest opportunities for the teacher to intercede and preserve the self-instructional nature of the materials, (2) that unit test results be more specifically related to the programed materials, and to alternate activities for enrichment or remedial study.

Demonstrative

1. The study indicates that teachers who prepared during the summer feel confident with the approach after one or two months. Where supervisory assistance and training are coincidental, supervisory assistance throughout the year can be anticipated in most instances. After teachers have had one year's experience, it seems apparent that they have developed the leadership potential to assist other teachers in elementary science, either by adopting the programed approach or by modifying instructional techniques to include more self-study and activity-centered experiences. The demonstration of the approach seems particularly suited to in-service training largely involving local school personnel.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The study supports the use of the programed science materials, coupled with the individual student performance of laboratory experiences, as an effective demonstration of curricular materials and new methods which allow individual rates of progress and performance of concrete activities. The integration of content, method, and laboratory experiences with a statement of behavioral objectives offers several advantages in the training, and demonstration of this approach:

1. The teachers become critically involved in the learning process of the child, relating method to content in adapting for individual differences.

2. Exposure to a range of science units and laboratory experiments instills confidence in those teachers whose background in science is limited to certain areas and whose experience in teaching science has avoided experimentation.

3. The involvement of supervisory and administrative personnel and the full utilization of school equipment and facilities is encouraged by a demonstration of the feasibility of the self-instructional process and the individual student performance of experiments.

4. The demonstration of this approach relates the implementation of such a project to the developmental stages by extending the field testing of materials to an evaluation of the instructional techniques compatable with such an approach. The difficulties encountered by teachers and the recommendations suggested by them are essential to the development of a more flexible use of the program.

5. The demonstration of the programed approach lends itself to the observation of pupil behaviors and related instructional techniques; and, as such, offers a concrete basis for the evaluation of an in-service training program or supervisory procedures.

The findings of the demonstration project recommend the following research and development emphases:

1. The development of new curriculums should integrate the instructional techniques with the presentation of materials, and the evaluation of the curriculum should extend beyond the field-testing of materials to an appraisal of the instructional

techniques. The demonstration project suggested the need to include instructional procedures which complement the materials development. Too frequently, the adaptative features of a curriculum have not been successfully realized in the developmental stages and implementation is undertaken without the specification of instructional methods.

2. The research in programed instruction might evidence more success in the training of teachers and in the demonstration of the use of the programed approach as an adjunct to the curriculum. The self-instructional feature of the materials and the statement of behavioral objectives are particularily useful in developing an instructional system which encourages a critical evaluation of the materials and a student-centered learning situation.

3. The study indicates the critical need to develop a more effective evaluation of programed materials before the efficient production of materials can be accomplished. Silberman (63) and Glaser (29) have cited the need to identify specific structural features of programs or the properties of programs which contribute to their effectiveness. The use of the computer is recommended as a research tool to determine why a program is effective and when the programed approach is desirable. As the use of programed materials becomes more flexible, the computer provides a method to simulate the monitoring function of the teacher. Study underway at the Bureau of Educational Research (49) suggests that an automated analysis of program structure will provide an effective guide to the writing and revision of materials; and, as an evaluative model, indicate the nature and extent of the influence of instructional strategies on student performance and program structure.

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APPENDIX A

Checklist of Eight Pupil Behaviors Using the Programed Science Materials

Date ______________________________

School, Class ______________________

Observer ___________________________

CLIMATE -- PUPILS

1.	Read programed text with little sign of attention wandering.	_ _ _ _ _ _ _	1.	Were restless, gazed about, doodled, daydreamed or wasted time at desks.
2.	Performed experiments with little confusion, chatter, etc.	_ _ _ _ _ _ _	2.	Loitered over the experiment table or sheer play at experiment table.
3.	Evidenced understanding of the purpose of the experiment. Became "science minded," performed experiments but varied them or their own accord to see what would happen.	_ _ _ _ _ _ _	3.	Reluctant to ask questions, or inhibited at experiment table.
4.	Students were aware of this approach to teaching; i.e., understood leaving text to perform experiment; continue in text and asked for unit tests. (Understanding of the technique)	_ _ _ _ _ _ _	4.	Needed excessive guidance at experiment table or in the programed approach.
5.	Found their own rate of learning, did not emphasize or concentrate on page of other students, rush through work to perform an experiment, used cover sheets, etc. (Attitude toward instructional techniques).	_ _ _ _ _ _ _	5.	Proceeded too fast in book either by not reading carefully or by copying andwers, or pretended to work, copied answers.
6.	Reviewed for unit test and/or received criticism of results well.	_ _ _ _ _ _ _	6.	Asked other students or referred to text when taking unit tests, or showed little or no interest in test results.

CLIMATE - PUPILS (continued)

Date ______________________________

School, Class ______________________

Observer ___________________________

7.	Responded eagerly to begin work in science, attentive throughout period.	__ __ __ __ __ __ __	7.	Made rude remarks, were quarrelsome, irritable, whispered wandered around class or showed other signs of inattention.
8.	Paid close attention to teacher or supervisor.	__ __ __ __ __ __ __	8.	Were slow in responding to teacher's or supervisor's requests.

Use the back of this sheet to relate critical incidents or document observations.

APPENDIX B

Program and Program Participants in the Evaluation Conference
August 9-10, 1967

SCIENCE DEMONSTRATION PROJECT
FOLLOW-UP CONFERENCE

Room 24 - Old Cabell Hall
University of Virginia

PROGRAM

August 9	10:30-11:00	Review of the development and current status of the programed science materials - Dr. Mary Ann MacDougall.
	11:00-11:30	Description of the science materials and the demonstration project workshop. Dr. Jeff A. Pyatte.
	11:30-12:30	Slides showing the materials in actual use. Mr. Charles L. Bertram (to be followed by a general discussion of the use of the materials in other situations).
	12:30-2:00	Lunch
	2:00-3:30	Continued discussion of the use of the materials and presentation of some preliminary findings from the demonstration project. - The group and Dr. MacDougall, Dr. Pyatte, Dr. Robert A. Shaw, Dr. Thompson.
August 10	8:45-9:30	Demonstration of Computer Assisted Instruction.
	9:30-10:45	Progress report on program development and content of the Florida State Intermediate Science Project: Dr. Herman M. Parker.
	10:45-11:15	Break.
	11:15-12:30	Progress report on program development and content of the American Association for the Advancement of Science, Elementary Project, Science - A Process Approach - Dr. Charles R. Davis.
	12:30-2:00	Lunch
	2:00-3:30	Progress report on program development and content of the Elementary Science Study - Mrs. Vivian Lightfoot.

PROGRAM PARTICIPANTS

Mr. Charles L. Bertram, Supervisor of Research Studies, State Department of Education, Richmond, Virginia.

Dr. Charles R. Davis, Supervisor of Science, Fairfax County Schools, Fairfax, Virginia; Member of Evaluation Team, American Association for the Advancement of Science, Elementary Science Program.

Mrs. Vivian Lightfoot, Consultant, Elementary Science Study, Educational Services, Inc., Newton, Massachusetts.

Dr. Mary Ann MacDougall, Acting Director, Bureau of Educational Research, and Associate Professor of Education, University of Virginia, Charlottesville, Virginia (Principal Investigator, Demonstration Project).

Dr. Herman M. Parker, Professor of Aerospace Engineering, University of Virginia, Charlottesville, Virginia; Member of the Advisory Committee and Member of the Writing Team, Florida State Intermediate Science Project.

Dr. Jeff A. Pyatte, Assistant Professor of Education, University of Virginia, Charlottesville, Virginia.

Dr. Robert A. Shaw, Assistant Professor of Education, University of Connecticut, Stors, Connecticut.

Dr. Ertle Thompson, Associate Director, NSF Institute, University of Virginia, Charlottesville, Virginia.

APPENDIX C

Key to Variables Analyzed by Multivariate Analysis

Key to Variables Analyzed by Multivariate Analysis

No.	Variable
1	Intelligence
2	Pre STEP
3	Pre True-False
4	Post STEP
5	Post True-False
6	Age (in months)
7	Sound test
8	Light test
9	Heat test
10	Plants and Animals test
11	Land, Water and Air test
12	Weather test
13	Earth and Sun test
14	Plants and Animals Living Together test
15	Fourth grade
16	Fifth grade
17	Sixth grade
18	Boy
19	Girl
20	Post STEP A
21	Post STEP B
22	Pre STEP A
23	Pre STEP B
24	Level 1 - Classroom Climate
25	Level 2 - Classroom Climate
26	Level 3 - Classroom Climate
27	Unit vector

APPENDIX D

Rationale for Analysis
Taken from Bottenberg and Ward (5)

Careful consideration of this outline in conjunction with Figures 1, 2, and 3 will disclose the logic governing the sequence in which estimates for restricted models should be obtained for *any* problem of this type. The numbers in parentheses refer to sections of the text which fully describe the analyses.

Sequence of Tests of Hypotheses

Question	Mathematical Expression	Analysis	Answer	Figure
1. Is amount of change in criterion per unit of concomitant variable the *same* for both treatments over observed range of concomitant variable?	$k_3 = k_4$	(5.2.4.1)		
			Yes	1
			No	2 or 3
Given $k_3 = k_4$				
2. Are the two treatments *equally* effective over observed range of the concomitant variable?	$k_1 = k_2$, i.e., $d = k_1 - k_2 = 0$	(5.2.4.2)		
			Yes	1 (superimposed lines)
			No	1
Given $k_3 \neq k_4$				
3. At what point (a_0) on concomitant variable may both treatments be expected to be equally effective? Is a_0 within range of interest?	If a_0 is estimate of m_0 (in Fig. 3), $a_0 = \dfrac{k_2 - k_1}{k_3 - k_4}$	(5.2.4.3)		
			Yes	3
			No	2

The flowchart in Figure 4 outlines the sequence of steps necessary for comparing the effects of two treatments when a concomitant variable may be operative. The principles that determine this sequence are applicable to problems involving several treatments and several concomitant variables. In such problems, however, there are more relationships possible between the criterion and concomitant variables; and these relationships may differ from treatment to treatment. If the relationships do differ, any conclusion about the superiority of a treatment is contingent upon the range of values of the concomitant variables that are considered simultaneously. However, when the relationships can be shown to be constant from treatment to treatment, the determination of which one of several treatments is superior can be made by following a sequence of steps analogous to that shown in Figure 4 for two-treatment problems.

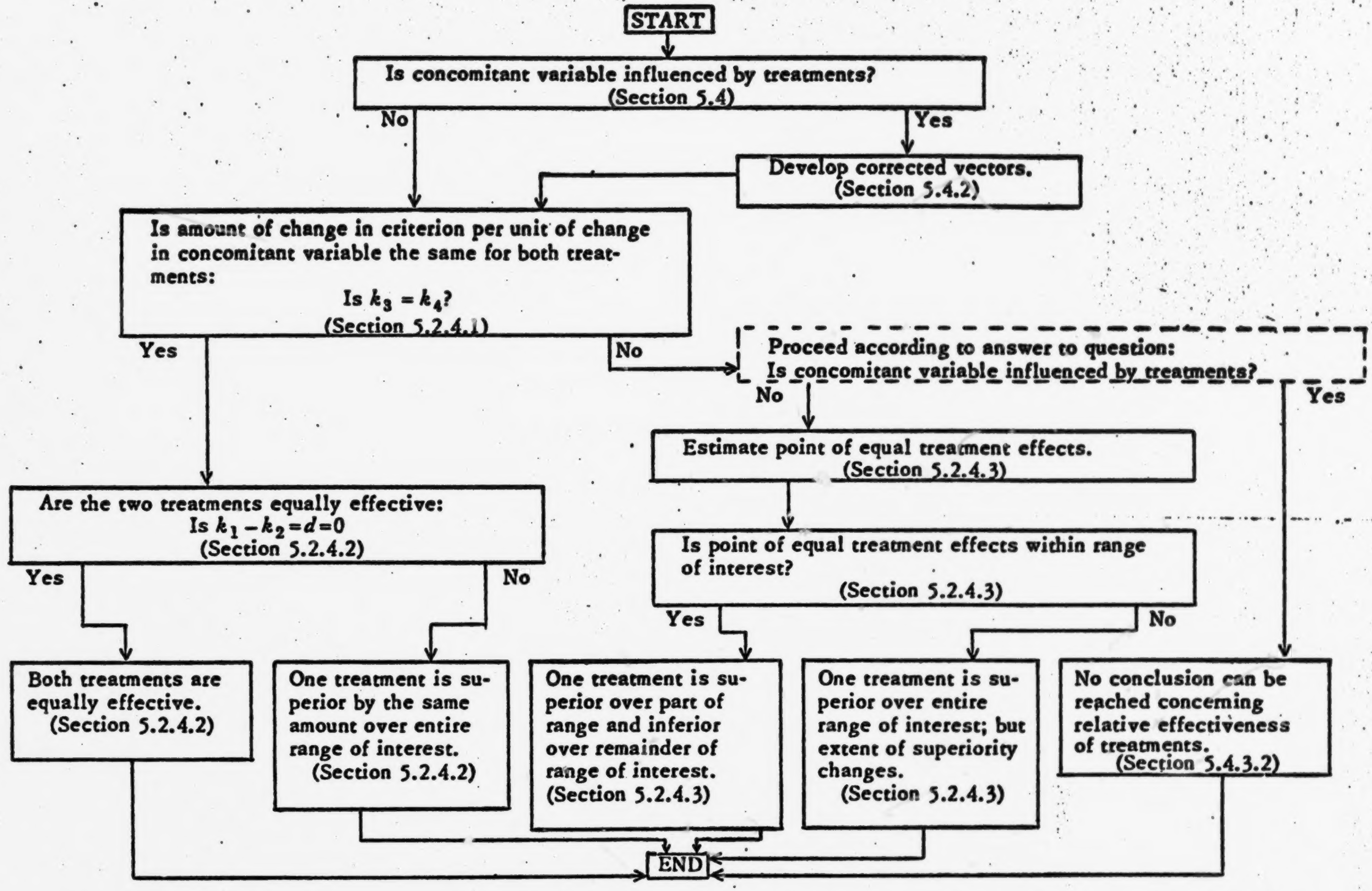
START
Is concomitant variable influenced by treatments? (Section 5.4)
No
Yes
Develop corrected vectors. (Section 5.4.2)
Is amount of change in criterion per unit of change in concomitant variable the same for both treatments: Is $k_3 = k_4$? (Section 5.2.4.1)
Yes
No
Proceed according to answer to question: Is concomitant variable influenced by treatments?
No
Yes
Estimate point of equal treatment effects. (Section 5.2.4.3)
Are the two treatments equally effective: Is $k_1 - k_2 = d = 0$ (Section 5.2.4.2)
Yes
No
Is point of equal treatment effects within range of interest? (Section 5.2.4.3)
Yes
No
Both treatments are equally effective. (Section 5.2.4.2)
One treatment is superior by the same amount over entire range of interest. (Section 5.2.4.2)
One treatment is superior over part of range and inferior over remainder of range of interest. (Section 5.2.4.3)
One treatment is superior over entire range of interest; but extent of superiority changes. (Section 5.2.4.3)
No conclusion can be reached concerning relative effectiveness of treatments. (Section 5.4.3.2)
END

Fig. 4. Flowchart showing sequence of steps necessary for comparing effects of two treatments when a concomitant variable may be operative.

APPENDIX E

Generating Procedure for Sequence of Tests of Hypotheses, Check for Tests, and Results of Tests

Generating Procedure for Sequence of Tests of Hypotheses

A. Multiply 24, 25, 26
by 1, get 28, 29, 30
by 2, get 31, 32, 33
by 3, get 34, 35, 36

B. Multiply 15, 16, 17
by 1, get 37, 38, 39

C. Multiply 18, 19
by 1, get 40, 41
by 2, get 42, 43
by 3, get 44, 45
by 6, get 46, 47

Check - Complete and Incomplete Groups

Dependent	Independent Variables
Full 4	24 - 27, 28 - 30
Rstr. 4	24 - 27, 1
Full 4	24 - 27, 31 - 33
Rstr. 4	24 - 27, 2
Full 4	15 - 17, 27, 37 - 39
Rstr. 4	15 - 17, 1, 27
Full 4	18 - 19, 27, 40 - 41
Rstr. 4	18 - 19, 27, 1
Full 4	18 - 19, 27, 42, 43
Rstr. 4	18 - 19, 27, 2
Full 4	18 - 19, 27, 44, 45
Rstr. 4	18 - 19, 27, 3
Full 4	18 - 19 - 27, 46, 47
Rstr. 4	18 - 19, 27, 6

Repeat for all models using 5 as dependent variable for complete and incomplete groups.

Results

Concomitant variance was observed as follows:

Incomplete Group

dependent	independent	F	p
4	18 - 19 and 6	4.31	.03
5	24 - 26 and 2	4.11	.017
5	18 - 19 and 1	4.88	.027

Complete Group

dependent	independent	F	p
4	18 - 19 and 2	3.99	.046

No F-ratio reached the .01 level; the 4 cases presented above were significant beyond the .05 level.

APPENDIX F

Generating Procedure and Check for Comparing Treatment Effects when a Concomitant Variable may be Operative

Generating Procedure and Check for Comparing Treatment Effects When a Concomitant Variable may be Operative

Incomplete Group

Model	Dependent Variable				
A	4	$46 - M_{46}$	48	Add 48 + 49	50
		$47 - M_{47}$	49		
B	5	$31 - M_{31}$	51		
		$32 - M_{32}$	52	Add	54
		$33 - M_{33}$	53		
C	5	$40 - M_{40}$	55	Add 55 + 56	57
		$41 - M_{41}$	56		

Complete Group

D	4	$42 - M_{42}$	58	Add 58 + 59	60
		$43 - M_{43}$	59		

Check

Model	F-ratio	P
A	4.31	.04
B	8.23	.004
C	4.88	.03
D	3.4	.05

APPENDIX G

TABLE IV

Analysis of the Effects on Achievement Attributed to Variables Listed - Complete Group

TABLE V

Analysis of the Effects on Achievement Attributed to Variables Listed - Incomplete Group

TABLE IV

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT ATTRIBUTED TO VARIABLES LISTED - COMPLETE GROUP

N=369

	Variables Dependent	Variables independent	RSQ	F-ratio	p	df_1	df_2
Full Model	4	1,3,6,18-19,24-26,27,60	.6268				
Restricted Models							
1. Delete intelligence (1)			.5910	34.65	**	1	361
2. Delete age (6)			.6233	3.38	.06	1	361
3. Delete sex (18-19)			.6248	1.89	.17	1	361
4. Delete classroom climate (24-26)			.6260	.76	.36	2	361
Full Model	5	1,2,3,6,18-19,24-26,27					
Restricted Models							
1. Delete intelligence (1)			.5278	10.99	.001	1	361
2. Delete age (6)			.5396	1.69	.19	1	361
3. Delete sex, (18-19)			.5416	.11	.74	1	361
4. Delete classroom climate (24-26)			.5340	3.06	.05	2	361

** beyond .001

TABLE V

ANALYSIS OF THE EFFECTS ON ACHIEVEMENT ATTRIBUTED TO VARIABLES LISTED - INCOMPLETE GROUP

N=328

	Variables		RSQ	F-ratio	p	df_1	df_2
	Dependent	Independent					
Full Model A	4	1,2,3,50,18-19,24-26,27	.6309				
Restricted Models							
1. Delete intelligence (1)			.6070	20.72	**	1	320
2. Delete pre STEP (2)			.5366	81.80	**	1	320
3. Delete pre True-False (3)			.6148	14.03	**	1	320
4. Delete sex (18-19)			.6301	.7149	.40	1	320
5. Delete classroom climate (24-26)			.6193	10.13	.002*	1	320
Full Model B	4	1,2,3,6,24-26,27	.6301				
Restricted Model							
1. Delete age (6)			.6299	.26	.60	1	321
Full Model A	5	57,54,3,6,18-19,24-26,27	.3591				
Restricted Models							
1. Delete age (6)			.3590	.02	.88	1	320
2. Delete sex (18-19)			.3574	.85	.36	1	320
3. Delete classroom climate (24-26)			.3523	1.68	.19	2	320
Full Model B	5	1,54,3,6,24-26,27	.3574				
Restricted Model							
1. Delete intelligence (1)			.3513	3.03	.08	1	322

**beyond .001

* beyond .01

APPENDIX H

TABLE VI

Analysis of the Effects on Unit-Test Achievement Attributed to Variables Listed - Complete Group

TABLE VI

ANALYSIS OF THE EFFECTS ON UNIT-TEST ACHIEVEMENT ATTRIBUTED TO VARIABLES LISTED

-COMPLETE GROUP, N=369

Full Model	Dependent	Independent
	7	1,2,3,6,18-19,24-26,27

Repeat for dependent variables 8,9,10,11,12,13,14

Dependent Variable	Restricted Models	F	p
7 (Sound)	1. Delete 1	24.48	xx
	2. Delete 6	3.31	.07
	3. Delete 18-19	.68	.41
	4. Delete 24-26	1.58	.21
8 (Light)	1. Delete 1	32.04	xx
	2. Delete 6	--	--
	3. Delete 18-19	.13	.72
	4. Delete 24-26	4.862	.01
9 (Heat)	1. Delete 1	17.84	**
	2. Delete 6	--	--
	3. Delete 18-19	.04	.86
	4. Delete 24-26	.98	.37
10 (Plants and Animals)	1. Delete 1	22.47	xx
	2. Delete 6	6.09	.01
	3. Delete 18-19	2.18	1.40
	4. Delete 24-26	.352	.71
11 (Land, Water and Air)	1. Delete 1	6.46	.01
	2. Delete 6	1.13	.29
	3. Delete 18-19	--	--
	4. Delete 24-26	.46	.63
12 (Weather)	1. Delete 1	12.90	xx
	2. Delete 6	--	--
	3. Delete 18-19	.32	.57
	4. Delete 24-26	2.44	.09

(Table VI - Cont.)

13 (Earth and Sun)	1. Delete 1	18.67	**
	2. Delete 6	.53	.47
	3. Delete 18-19	2.80	.10
	4. Delete 24-26	.54	.08
14 (Plants and Animals Living Together)	1. Delete 1	19.78	**
	2. Delete 6	.04	.85
	3. Delete 18-19	1.32	.25
	4. Delete 24-26	.01	.10

Where,

1 = intelligence

6 = age

18-19 = sex

24-26 = Teacher climate

** beyond .01 level of significance

APPENDIX I

TABLE VII

Possible Score, Means and Standard Deviations of Eight Unit Tests, Complete Group

TABLE VII

POSSIBLE SCORE, MEANS AND STANDARD DEVIATIONS OF EIGHT UNIT TESTS, COMPLETE GROUP

Test	Possible Score	Mean	SD
Sound	34	24	5.2
Light	38	24	6.8
Heat	29	19	5.5
Plants and Animals	50	35	7.4
Land, Water and Air	38	32	5.7
Weather	27	17	5.1
Earth and Sun	33	24	6.5
Plants and Animals Living Together	22	17	3.8

APPENDIX J

TABLE VIII

Means and Standard Deviations of Student Characteristics Sorted by Sex

TABLE IX

Means and Standard Deviations of Student Characteristics Sorted by Classroom Climate

TABLE VIII

MEANS AND STANDARD DEVIATIONS OF STUDENT CHARACTERISTICS SORTED BY SEX

Complete Group

Variable	Boys, N=187		Girls, N=182	
	Mean	SD	Mean	SD
Intelligence	100.04	14.18	103.41	15.48
Pre STEP	33.88	11.30	33.91	9.78
Pre True-False	115.67	18.32	112.68	17.32
Post STEP	37.61	10.69	36.71	10.52
Post True-False	131.61	18.04	131.54	16.37
Age (in months)	123.89	12.58	120.20	11.92

Incomplete Group

Variable	Boys, N=165		Girls, N=163	
	Mean	SD	Mean	SD
Intelligence	87.17	15.04	91.84	15.51
Pre STEP	28.24	10.93	29.90	10.86
Pre True-False	111.09	16.22	111.11	15.03
Post STEP	30.16	11.67	32.52	9.68
Post True-False	120.28	22.95	123.83	19.42
Age (in months)	137.73	17.14	130.80	14.25

TABLE IX

MEANS AND STANDARD DEVIATIONS OF STUDENT CHARACTERISTICS SORTED BY CLASSROOM CLIMATE

Complete Group

	Level I		Level II		Level III	
	N=148		N=188		N=33	
Variables	Mean	SD	Mean	SD	Mean	SD
Intelligence	101.59	14.06	102.01	15.51	102.97	15.12
Pre STEP	34.42	10.21	33.82	10.88	31.79	10.16
Pre True-False	112.42	16.91	115.01	18.86	117.54	15.61
Post STEP	36.94	10.28	37.33	11.12	37.27	9.03
Post True-False	131.39	17.10	130.90	17.97	136.27	12.16
Age (in months)	123.86	11.77	120.51	13.02	122.91	10.13

Incomplete Group

	Level I		Level II		Level III	
	N=102		N=150		N=76	
Variables	Mean	SD	Mean	SD	Mean	SD
Intelligence	84.88	13.81	90.42	17.12	93.84	12.14
Pre STEP	29.98	11.37	28.29	10.95	30.68	10.08
Pre True-False	112.60	15.29	109.92	16.29	111.42	14.56
Post STEP	31.94	11.53	31.07	10.81	31.04	9.62
Post True-False	123.33	21.99	121.84	22.04	120.72	18.84
Age (in months)	141.84	13.36	129.67	17.53	131.06	11.69

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION

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TITLE
THE TEACHING OF UPPER ELEMENTARY SCHOOL SCIENCE USING PROGRAMED MATERIALS COUPLED WITH STUDENT PERFORMED EXPERIMENTS

PERSONAL AUTHOR(S)
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RETRIEVAL TERMS

programed instruction
science
teacher training
elementary curriculum

instructional technology
programed science
individualized instruction

IDENTIFIERS

ABSTRACT

The major purpose of the study was to demonstrate via selected upper elementary teacher, supervisors and principals throughout Virginia the curricular materials and new methods developed for enabling students to study science at varying rates of progress and to perform individually science experiments. The programed materials were first used in the in-service training of teachers as a means of acquiring knowledge and skill in science and an understanding of the techniques and rationale of the programed approach. The approach was implemented in twenty-three classes, where supervisory and demonstration procedures were appraised. A secondary purpose of the study was to analyze the relationships between student performance and related classroom and learner variables. Major outcomes of the study are: (1) student and teachers were enthusiastic and/or favorable towards this approach and procedures were effectively implemented, (2) students followed the programed procedures with minimum of direction, (3) a courteous, patient and sympathetic atmosphere typically prevailed in the classrooms, (4) teachers became increasingly independent, (5) supervisory and administrative involvement was cooperative and effective, (6) the analysis of student performance indicated the influence of the classroom climate and student variables, intelligence and initial science achievement, maturity, sex, and grade level.